

Portable Radiation Detector Provides Laboratory-Scale Precision in the Field

UNTIL recently, the U.S. relied on large oceans and friendly bordering countries to provide security against a terrorist attack. It was believed that an attack would most likely arrive in the form of missiles launched from land, air, or sea.

The terrorist threat now lies much closer to home. Experts believe that a possible method of weapon delivery will be a suitcase concealing contraband radioisotopes hidden in a car or plane's luggage compartment. Or a seemingly harmless shipment of medical or industrial radioisotopes could mask potent radioisotopes destined for a dirty bomb—an ordinary explosive laced with radioactive material. To counter such threats, security agencies are looking for a new generation of portable radiation detection devices that will allow military, law-enforcement, public-health, and medical personnel to easily and quickly identify radioactive materials and distinguish among them.

Devices that detect x and gamma rays have been available for a few decades. However, precision energy-resolution detection devices, which unambiguously identify radioisotopes, are large and power-intensive and require a consumable liquid cryogen, all of which make them difficult to use in the field. A Lawrence Livermore team has developed a portable, handheld germanium radiation detector called CryoFree/25 that can duplicate the energy resolution and efficiency of a laboratory gamma-ray spectrometer. Physicist John Becker and engineers Norman Madden, Lorenzo Fabris, and Chris Cork are collaborating on the project. Begun in 1998, the project is sponsored by the Department of Energy's Office of Nonproliferation Research and Engineering, which is part of the Office of Defense Nuclear Nonproliferation.



In CryoFree/25, a hermetically sealed germanium gamma-ray detector is coupled to a small, low-power cooler that is available commercially. The unit weighs 4.5 kilograms and can operate for 7 to 8 hours on two rechargeable lithium-ion batteries.

"The team's goal," says Madden, "was to create the smallest possible handheld, mechanically cooled gamma-ray spectrometer with the largest amount of germanium. The more germanium, the higher the detection efficiency." As part of Livermore's Measurements Science Team, originally formed at Lawrence Berkeley National Laboratory and now part of the Physics and Applied Technologies Directorate, the team had previously developed technology for a radiation detector that is onboard a NASA spacecraft. Becker thought it would be worthwhile to explore terrestrial applications for the radiation detector.

Powerful and Lightweight

Developed under the name Cryo3 but now dubbed CryoFree/25, this technology makes a quantum leap forward in portable radiation detection. The detector system features a handheld, gamma-ray spectrometer and book-size auxiliary equipment, such as a portable computer, power supply, and conditioning units. The gamma-ray spectrometer nearly replicates the precision energy resolution found in the larger, less-portable laboratory units used for unambiguous radioisotope identification.

The unit weighs less than 4.5 kilograms and can run for 7 to 8 hours on two rechargeable lithium-ion batteries. CryoFree/25 operates on only 16 watts of dc power and can operate continuously for more than 6 months before the unit's cooling mechanism needs a short recycling period. "The beauty of CryoFree/25 is that the device can deliver the level of gamma-ray energy resolution associated with laboratory germanium spectrometers in a portable, lightweight, germanium detector without liquid nitrogen and with long field life," says Becker.

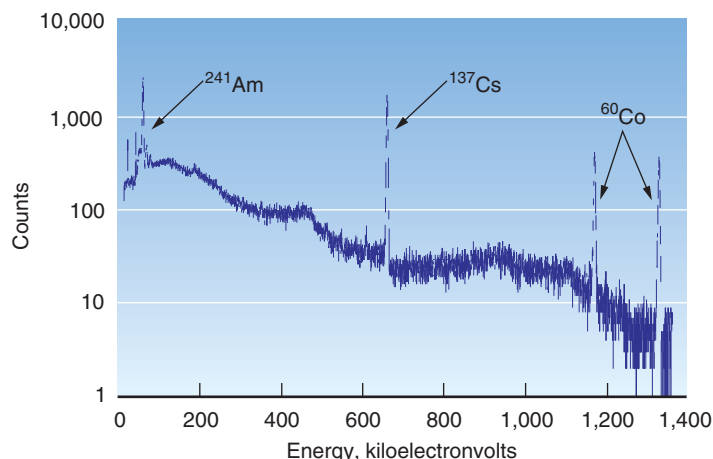
Germanium has long been the detector material of choice for precision gamma-ray spectroscopy. Compared with other semiconductor materials used in detectors, such as silicon or cadmium telluride, germanium provides better detection efficiency, line-shape characteristics, and precision energy resolution, which are needed to produce the detailed x- or gamma-ray spectra for identifying radioactive materials. The germanium crystals must be cooled to approximately 90 kelvins (about -300°F) to operate. Liquid nitrogen has been the cryogen of choice, but more than 10 liters per week of liquid nitrogen are required to cool an average laboratory-size detector. This cooling requirement makes standard detectors awkward to transport, store, and handle in the field. Access to liquid nitrogen is a requirement for routine use.

Becker's team overcame the size and access problems by joining the germanium crystal to a commercially available mechanical device commonly used to cool low-noise cell-phone antennas. The device, originally designed for the aerospace industry, requires only 12 watts to cool the germanium. "Our innovation is coupling a germanium radiation detector with a small, low-power cryogenic cooling mechanism," explains Madden. "This combination offers extremely high-resolution gamma-radiation analysis in a portable package."

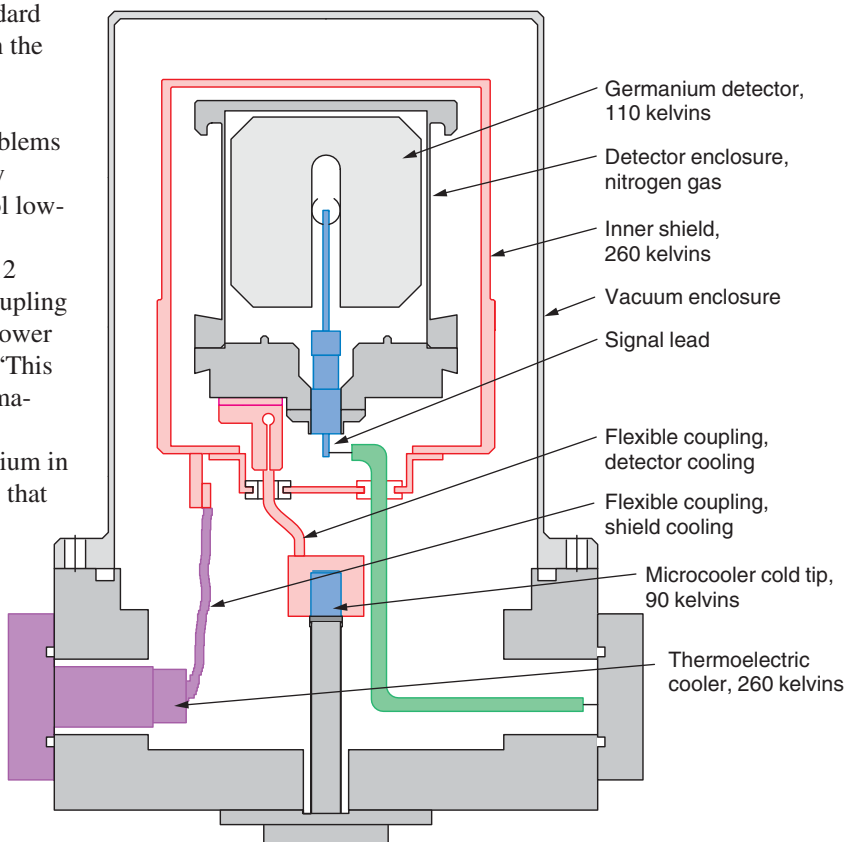
As gamma-ray photons interact with the germanium in CryoFree/25, their energy is converted into charges that can be measured and recorded. Every radioisotope has a unique gamma-ray signature, which can be inferred by measuring the magnitude of the charge created in the detector and processed by the detector's electronics. Unlike many other detectors, CryoFree/25 can identify all of the gamma rays originating from the known radioisotopes.

Adaptable for Multiple Applications

"CryoFree/25 is a forensics science tool for gamma-ray detection," says Madden. "The resolution of the CryoFree/25 is so precise that it provides a unique fingerprint of the sample. For example, the detector can reveal not only



As gamma-ray photons illuminate the CryoFree/25 detector, their energy is converted to electrical signals that can be measured and recorded. Every radioisotope has a unique signature. Shown are the combined characteristic fingerprints of americium-241, cobalt-60, and cesium-137 radioisotopes.



The germanium detector is hermetically encapsulated within a thin layer of aluminum that contains a nitrogen blanket. An external metal "getter" and a miniature ion pump are used to maintain the utility vacuum.

what radioisotope is present but also the history of the radioisotope—whether, for instance, it came from a spent fuel rod or another source and how long ago the chemical alteration to the radioisotope occurred. The device might even reveal approximately where the alteration occurred.”

In addition to finding a cooling mechanism for the portable unit, the Livermore team added signal-processing electronics to minimize electronic noise that would otherwise obscure the detector’s energy resolution. A readout that shows detector pulse height with sharp, defined peaks accurately depicts the types and amounts of radiation present.

The Livermore team is working with the Coast Guard to adapt the unit for use on shipping vessels. “The Coast Guard needs the least obtrusive, most rugged and lightweight unit with proven reliability,” says Madden. CryoFree/25’s small size makes it particularly attractive for applications where small spaces may obscure field use of other detectors, such as at border crossings, airport terminals, and cargo ports.

The group is applying the same detector technology used in CryoFree/25 for space applications. Last year, an expanded team from Lawrence Livermore and the Space Science Laboratory at the University of California at Berkeley, delivered a flight detector to Johns Hopkins

Applied Physics Laboratory for research on a NASA spacecraft designed to retrieve radioisotope data on the geochemistry of Mercury. CryoFree/25 technology may also prove valuable for the Department of Energy’s work in monitoring the nation’s nuclear weapons stockpile and protecting the weapons and nuclear energy facilities from terrorists.

The team is hopeful that government agencies will take advantage of the portable unit’s technology, which can be adapted to many applications. In emergencies, where time and power outages may limit the ability of laboratories to process radiation samples, CryoFree/25 provides the unambiguous radioisotope identification that is required to protect vital resources.

—Gabriele Rennie

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